

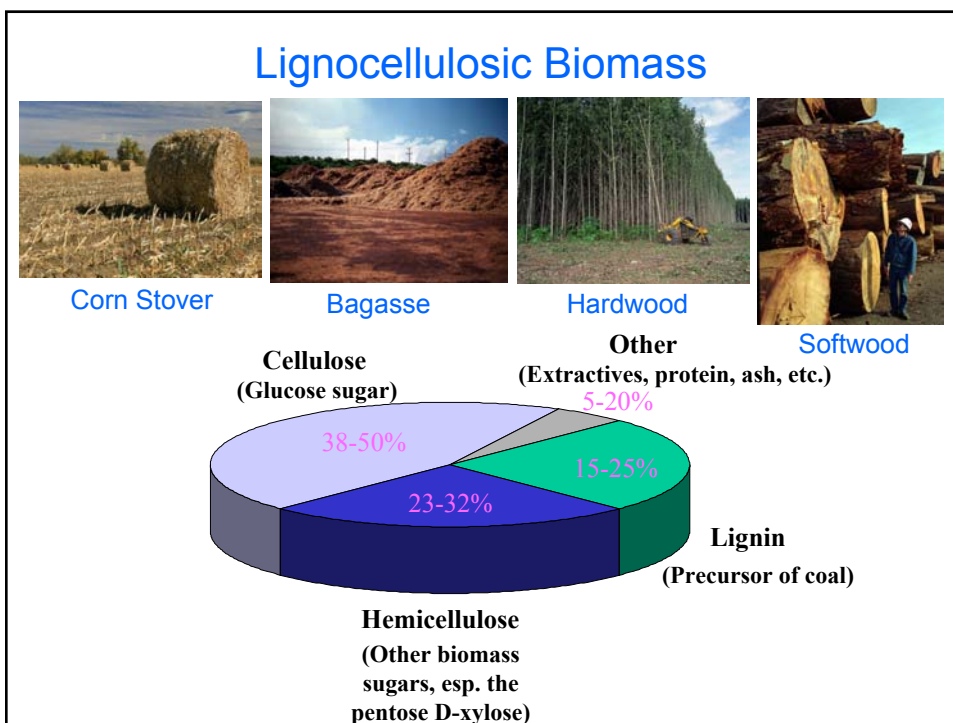

Ethanol From Cellulosic Materials

Rick Elander
Pretreatment R&D Team Leader
Biotechnology Division for Fuels and Chemicals
National Renewable Energy Laboratory
Golden, CO

U.S. DOE Fuel Ethanol Workshop
Honolulu, HI
November 14, 2002

U.S. Department of Energy

Operated for the U.S. Department of Energy by Midwest Research Institute • Battelle • Bechtel

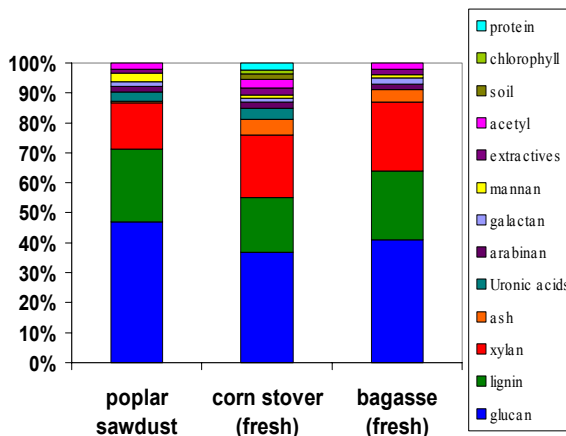




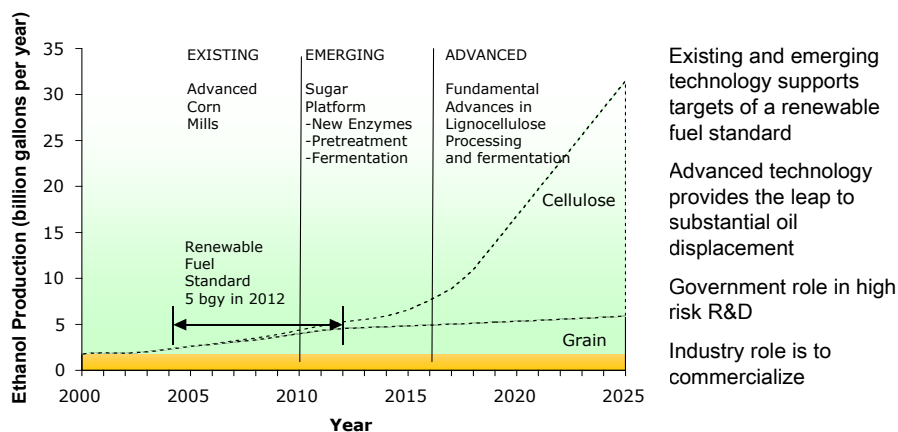
Corn Stover—the “hot” feedstock

- Up to 60 MM dry tons per year available from the 10 leading corn production states can be collected in a sustainable manner
 - erosion control
 - soil carbon levels
- Enough to produce over 4 billion gallons of ethanol per year

Stover and Bagasse—Many Similarities



Ethanol from Starch and Lignocellulose

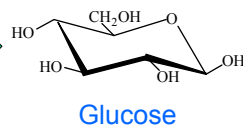
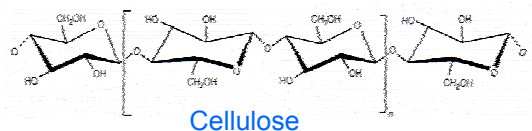


Lignocellulose Conversion Processes

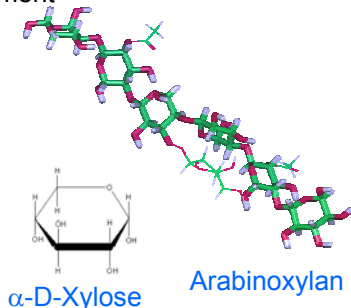
- Concentrated acid hydrolysis (sulfuric or hydrochloric acid)
 - Thermochemical hydrolysis of cellulose and hemicellulose
 - Relatively low temperature, requires acid recovery and recycle
- Dilute acid hydrolysis (sulfuric or hydrochloric acid)
 - Thermochemical hydrolysis of cellulose and hemicellulose
 - Relatively high temperature, no acid recovery
 - Difficult to achieve high glucose yields without complex reactor configurations
- Pretreatment/enzymatic hydrolysis
 - Partial to complete thermochemical hydrolysis of hemicellulose
 - Various pretreatment approaches available
 - Enzymatic hydrolysis of cellulose and any remaining hemicellulose
 - Enzymes are currently too costly

Challenges for Lignocellulosic Ethanol

Cellulose is much more recalcitrant than starch

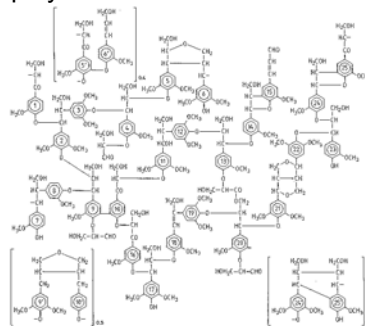


Hemicellulose largely consists of pentose sugars—more difficult to ferment

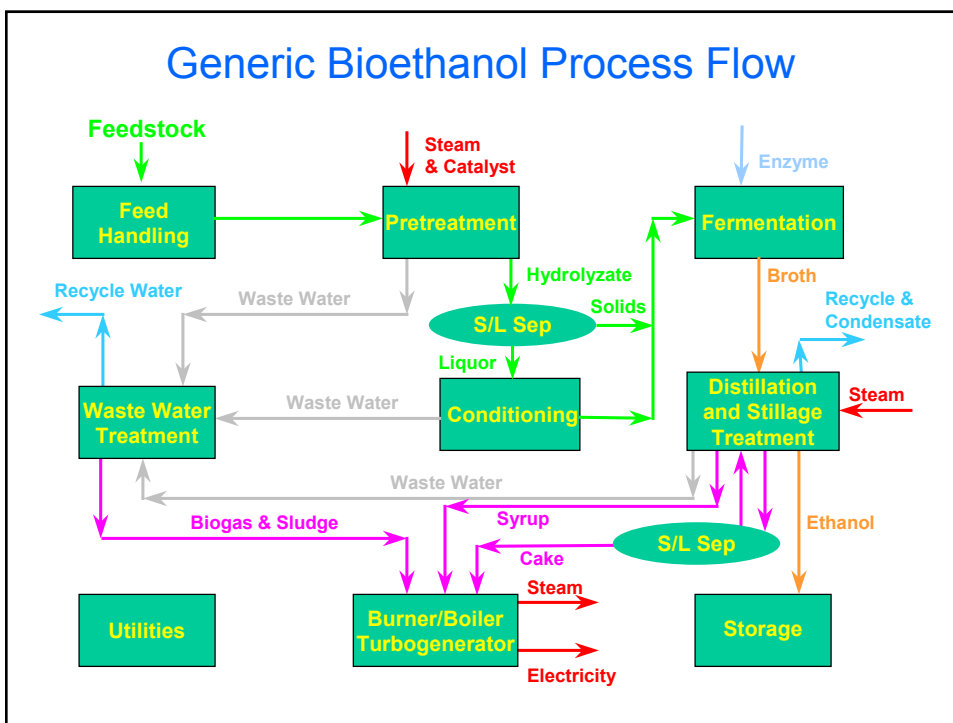


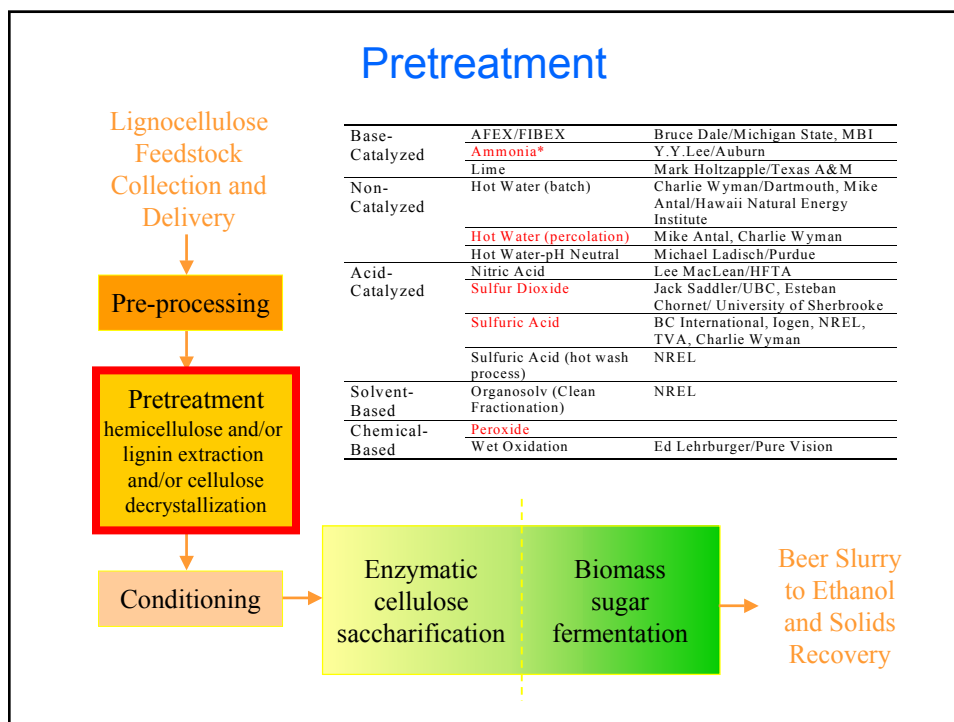
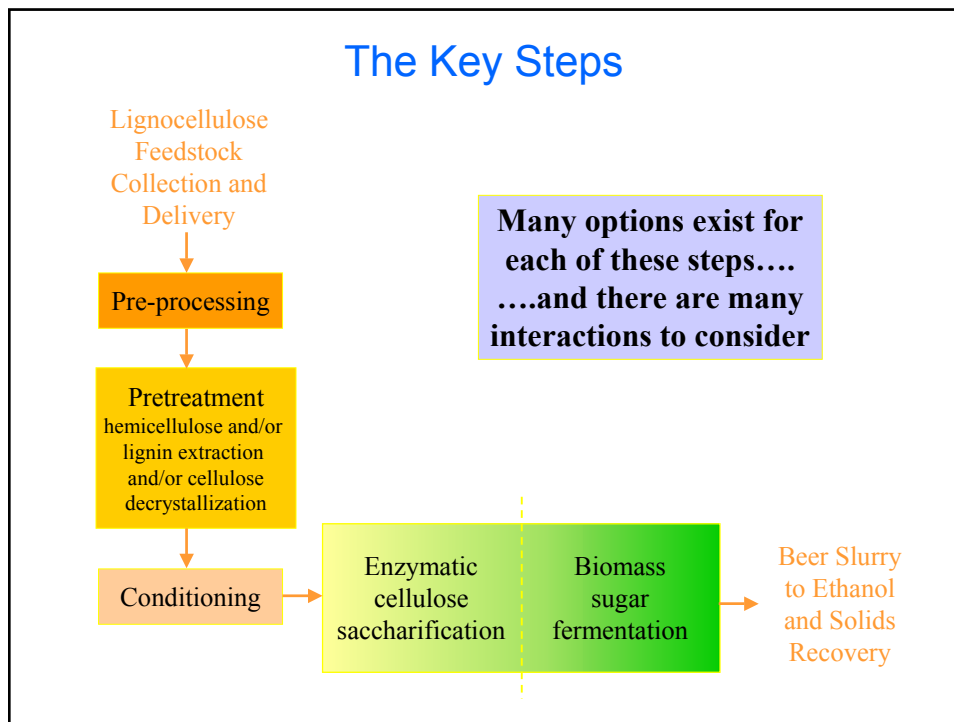
α -D-Xylose

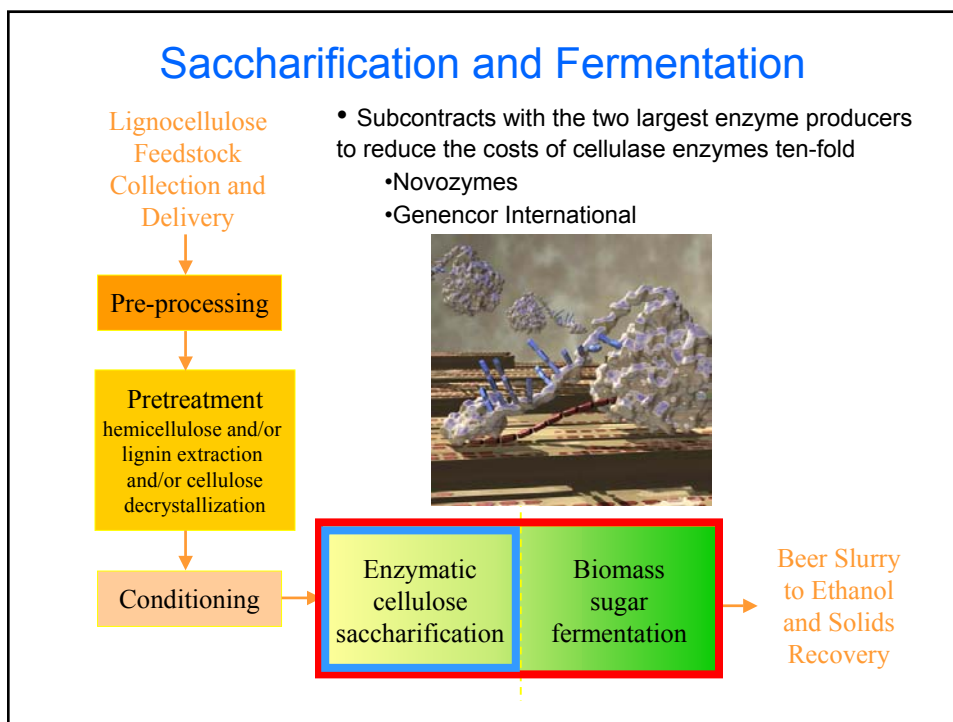
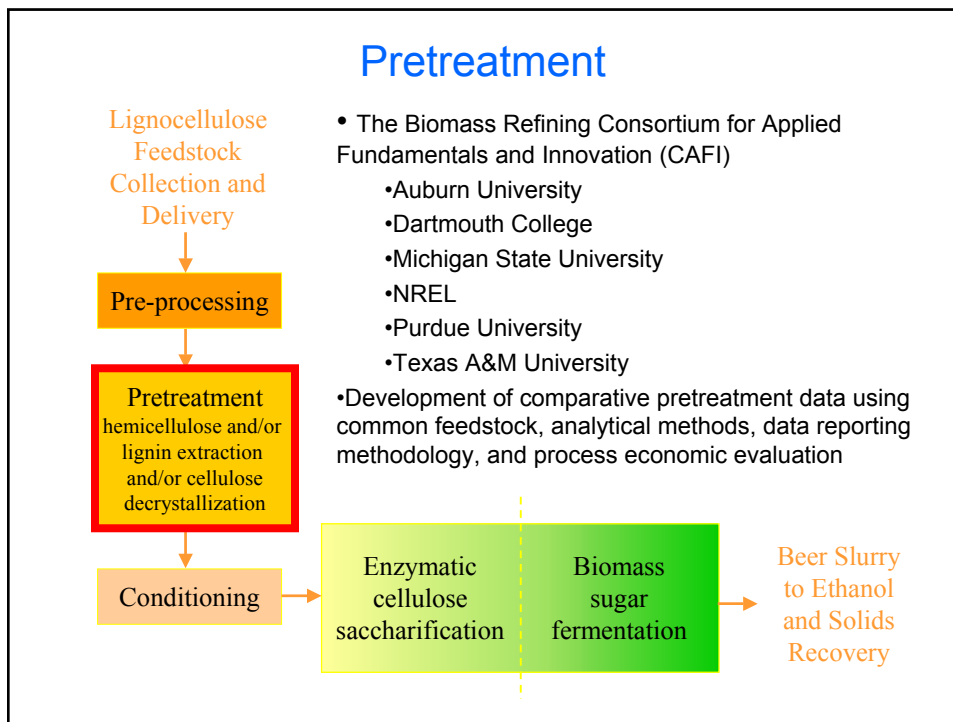
Lignin—a highly aromatic, refractory heteropolymer



Generic Bioethanol Process Flow







Saccharification and Fermentation

Lignocellulose
Feedstock
Collection and
Delivery

Pre-processing

Pretreatment
hemicellulose and/or
lignin extraction
and/or cellulose
decrySTALLIZATION

Conditioning

• Robust, co-fermenting organisms need further development

- Yeast (recombinant)
- Bacteria (recombinant)

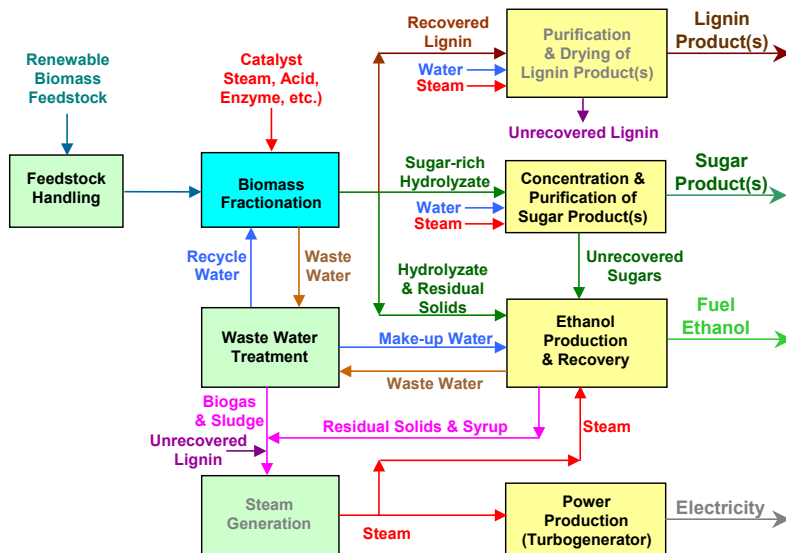


Enzymatic
cellulose
saccharification

Biomass
sugar
fermentation

Beer Slurry
to Ethanol
and Solids
Recovery

Sugar and Lignin Platform Biorefinery

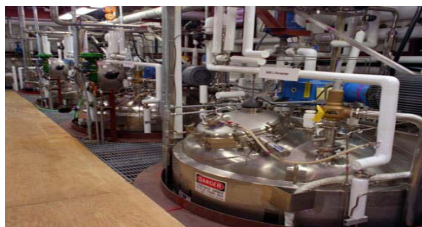


The Biotechnology Division for Fuels and Chemicals at NREL



<http://www.nrel.gov/biotechnology/>

<http://www.ott.doe.gov/biofuels/>



Acknowledgements

- U.S. Department of Energy, Office of Biomass Programs



- State of Hawaii; Department of Business, Economic Development & Tourism; Energy, Resources, and Technology Division
- BBI International